THE FIBRO-VASCULAR SYSTEM OF THE PEAR (POME).

By D. McAlpine, Corresponding Member.

(Plates xxvi.-xxix.)

I have already dealt in some detail with the vascular system of the apple (*antea*, p.613), and it is so closely related to that of the pear, that it will not be necessary to treat the latter with the same degree of fulness.

The fruits of the apple, pear, and quince, known as Pomes or Pip-fruits, are characterised by possessing five carpels, constituting the "core" or true fruit, and surrounded by a fleshy portion generally considered to be the swollen and succulent receptacle. The pulpy flesh of the pear and quince differs from that of the apple, however, in containing groups of what are known as "stone-cells" scattered among the thin-walled cells of the parenchymatous tissue. These constitute the "grit" of the pear and quince, and consist of cells with strongly thickened, lignified walls, hence called sclerenchyma.

Transverse and longitudinal Sections of Pear.

If a thin transverse section of the pear is made through the core, and phloroglucin used as a stain, followed by hydrochloric acid, the stone-cells turn a bright red colour; and while seen to be scattered through the flesh, extending even to the skin, they are densely clustered around the core(Fig.2). The pear likewise differs from the apple in being more or less top-shaped, so that the carpels are relatively nearer the crown or blossom-end, and not so central because there is a much larger proportion of the fruit representing the receptacular portion beneath the core(Fig.4). On this account, the primary vascular bundles are seen traversing the flesh for a greater portion of their course than in the apple, and a better insight is thereby gained into their relative positions before they reach the carpels.

The pears used in this investigation were Harrington's Victoria and Achan, because they happened to be preserved up to the month of September. It was found that, in the case of the pear, potassium hydrate was not necessary for softening purposes, as, after immersion for five days in ordinary tap-water, the skin could be easily peeled off, and the flesh removed by needle and brush, so that the vascular system stood out distinctly as shown in Figs.6, 7, and 8.

If we follow the course of the vascular bundles from the fruit-stalk, a connected view will be obtained from their entrance into the fruit, and they can then be followed right through until the blossom-end is reached.

Fruit-stalk.—The fruit-bud which is borne by the short shoot or "spur," will open out in the spring into a number of flowers, of which only one may "set" and produce fruit. The flower is really of the nature of a shoot, and the stalk represents the stem or axis. If a transverse section of the stalk is made just where it adjoins the flesh, ten distinct fibro-vascular bundles are seen (Fig.1), although, on account of irregularities in growth, these may often lose their distinctness, and run together. They are continued into the fruit, and constitute the ten primary vascular bundles which supply the rapidly growing fruit from the parent-tree.

Vascular System of "Core" and "Flesh."

A transverse section of the pear through the "core" shows the five cavities, each containing normally two seeds, enclosed by a fleshy wall with a firm inner face(Figs.2, 3). An irregular layer of "stone-cells" surrounds this, so that the ten vascular bundles, seen so prominently in the apple between and opposite to each of the carpels, are obscured. How densely the stone-cells are crowded, particularly opposite the carpels, may be seen in Fig.3. But if a transverse section does not reveal much of a vascular system from mere inspection, a longitudinal section gives a good insight into the general structure(Figs.4, 5). The continuation of the fruit-stalk is seen in the flesh, and the primary vascular bundles soon diverge from it. There are five bundles only slightly spreading at first, but as they approach the carpels, they bulge out more. As each one approaches its corresponding carpel, it gives rise to an internal branch, which passes along the dorsal or outer face of the carpel, while the main portion of each bundle is continued beyond to the blossom-end of the fruit. There are also five alternating bundles which diverge a little higher up than the preceding, and each one passes between two carpels, giving off an internal branch to the inner or ventral face of the carpel (Fig.6).

Each primary vascular bundle gives rise to numerous branches externally, which combine to form a complete network of vessels about one-half inch or less from the surface(Fig.9); and from the boundaries of each mesh, the innumerable plume-like branches arise, reaching to the skin, just as in the apple(Figs.4, 5, 6).

Fibro-vascular System as a whole.

The first impression gained by a glance at this luxuriant and elaborate system of vascular bundles in the pear(Fig.7) is, that it is provided with a most complete framework to support the soft parts, and is the centre of a great receiving and distributing agency, receiving food-materials from every part of the tree, and distributing them to every portion of the fruit. It is not only adapted for supplying present needs, but also for future requirements, as the food is used up or stored up, according to circumstances.

It is difficult to give an accurate description, conveying an idea of the diversity of the bundles and yet of their combination into a harmonious whole. But the general views of the entire system(Figs.7 and 8), the detailed views(Figs.6 and 9), together with the transverse and longitudinal sections(Figs.2, 3, 4 and 5), should help to give a vivid picture of the wonderful arrangements provided by nature for the building up of the luscious fruit, which is simply a vehicle for the distribution of the seeds.

The Skeleton.—Just as in animals, the skeleton is intimately associated with the conducting tissues, and each fibro-vascular bundle has a skeletal framework to stiffen and strengthen the vessels. In addition to that, the "stone-cells," so generally distributed throughout the pear, strengthen and protect the softer tissues, and being scattered in groups, they offer no impediment to increase in size. Even the skin, as shown in the account of the apple, acts as an outside skeleton, or exoskeleton, to give firmness to the whole, and keep the component parts together. If the skin is broken or bruised in a ripe pear, it is seen how quickly decay sets in; and even while the fruit is still growing, the skin must keep pace with the rapid enlargement. The structure of the skin, with its "window-cells," as in the apple (Fig.10), is adapted for expansion, but its chief function is to prevent a too rapid loss of water. As showing the efficiency of the skin for this purpose, I had a pear of the Broompark variety and a Jonathan apple, peeled and unpeeled, and kept in a dry atmosphere for 48 hours. The loss in weight was carefully tested by P. R. Scott, Chemist for Agriculture, with the following results :—

Weight of whole pear before desiccation .....261·569 gr., after 260·0355 gr.
Weight of peeled pear before desiccation..... 176·677 gr., after 172·5190 gr.
Weight of whole apple before desiccation. . 133·4895 gr., after 132·737 gr.
Weight of peeled apple before desiccation ..112·065 gr., after 108·8538 gr.

No.1.	Whole pear........	0·586	per cent.	loss after	48 hours.
No.2.	Peeled pear..	2·35	,,	,,	,,
No.3.	Whole apple.......	0·563	,,	,,	,,
No 4.	Peeled apple.......	2·87	,,	,,	,,

Thus the peeled pear had lost over four times the weight of that of the whole pear, and the pared apple had lost over five times that of the unpared.

The Conducting Tissue.

If we follow the course of the nutrient fluid, supplied by the root, stem, and leaf, from its entrance through the stalk, to nourish the fruit, it will give us a connected view of the whole system. This food is conveyed through ten primary bundles developed in connection with the carpels, although the fleshy portion, which is only accessory to the true fruit, is also nourished through them. The ten primary vascular bundles alternate with each other. Five of them are arranged opposite the five carpels, and each one gives off an internal branch as it approaches the carpel, to supply its outer or dorsal surface, and this conveys the nourshiment through a network of delicate branches radiating on either side of each carpel (Fig. 6). The main bundle is continued around the carpels to the blossom-end of the fruit.

The remaining five bundles run between the carpels (Fig. 6 in centre), and convey the nourishment to the inner or ventral face of each carpel. An internal branch is given off towards the base of each primary bundle (about $\frac{3}{4}$ inch from the top of the stalk), and these five branches run together in the centre until they approach the tapering basal end of each carpel. There each branch splits up into two parallel strands, which run along each side of the ventral face of the carpel, and these ten strands are clearly shown in Fig. 3. These also branch, and form a network on the surface of each carpel, so that, from the dorsal and ventral surfaces, there is a system of vessels which blend and leave no portion unprovided for (Figs. 5 and 6). As in the others, the main trunks pass around the carpels to the blossom-end.

There is here a beautiful illustration of the principle of the division of labour, for five of the vascular bundles, opposite the carpels, supply the dorsal surface of each; while five, between the carpels, provide for the ventral surface of each, and by a delicate system of branching, the entire surface of the carpel is liberally supplied with nutritive material. The ten strands, running alongside the ventral portion of the carpels, are continued along their whole length, for they are seen in sections either towards the base or the apex of the carpels.

While the seed-cavity, with its contained seeds, is the most important, and must be directly supplied, yet there is the most liberal provision made for the "fleshy" portion of the pear. From the outer surface of each primary vascular bundle, numerous branches are given off, which divide and subdivide until they form a complete network surrounding the "flesh" (Fig. 9); and from the boundaries of each mesh, innumerable plume-like branchlets are given off, ending in their delicate intertwining tufts immediately beneath the skin. Here a new supply of food-material is provided for, for the green chlorophyll-containing cells of the hypodermal layer (Fig. 12), in the presence of sunlight, manufacture starch, which is converted into sugar, and carried by the plume-like branches to the enveloping network, where it meets and blends with the ascending stream.

As regards the course followed by the food-materials, the most generally accepted theory is that the carbohydrates and the proteid substances follow two separate paths in their passage from the place of formation, the one through the "conducting parenchyma," and the other by means of the sieve-tubes.

But the view that these substances are exclusively conveyed in particular tissues is becoming modified, and Sachs, in his "Lectures on the Physiology of Plants," states at p.358, "In the case of a very vigorous transport of starch, as when the leaves of trees are being emptied in the autumn, even the phloem of the vascular bundles may take part in it."

The theory put forward by Czapek, in 1897, that the carbohydrates are transported by the sieve-tubes, is now gaining ground, particularly when they have to be carried for some distance. There are thus two possible ways in which food-materials may be transported—by the slow process of diffusion from cell to cell, when the solutions in each have different degrees of concentration; or more rapidly by means of the sieve-tubes, with their greater length, and pores in the transverse walls.

Vascular bundles in relation to each other.

It has finally to be noted, that the primary vascular bundles are not isolated from each other, but that they anastomose at various points. The branches which supply the core and the flesh ultimately form a network, the one enveloping each carpel (Fig. 6), and the other the flesh at a short distance from the surface (Fig. 9).

There are thus two main systems connected by means of a network of vessels, corresponding to the two principal constituents of the pome; and this wonderful vascular net, which is seen in the young fruit immediately after the petals have fallen, as well as in the mature fruit, is evidently for the purpose of regulating and equalising the distribution of the nutrient fluid to the seeds and the flesh respectively.

While the network is an evident means of intercommunication, there are other less conspicuous connections, such as the branches given off to supply the carpels being directly connected here and there by cross-partitions with the main bundles.

EXPLANATION OF PLATES XXVI.-XXIX.

Plate xxvi.

Fig. 1.—Transverse section of fruit-stalk, just as it enters the fruit, showing ten fibro-vascular bundles. The stalk was somewhat shrunken on account of the age of the fruit, and the section shows the woody tissue ruptured in nine of the ten bundles (× 30).

Fig. 2.—Transverse section of pear through the carpels near the blossom-end, showing the distribution of the "stone-cells." The section was placed in a solution of phloroglucin to which hydrochloric acid had been added, and the lignified walls of the stone-cells were stained a bright red.

Fig. 3.—Transverse section of portion of pear, similar to the preceding, showing the central core, with two bundles alongside of each other between the carpels. The indications of the ten primary bundles are not seen as in the apple, being obscured by the surrounding "stone-cells," which form very prominent groups opposite each of the carpels. The pair of bundles adjoining the inner face of each carpel represents the forking branch from each of the five intermediate main bundles (× 2).

Plate xxvii.

Fig. 4.—Longitudinal median section showing the "core" towards the blossom-end. The primary bundles are seen diverging from the stalk-end, and continuing round the carpels to the blossom-end; while, on the left side, the network is seen, together with the

plume-like branchlets radiating towards the skin. The dots scattered through the flesh indicate the stone-cells. (Slightly reduced).

Fig.5.—Diagrammatic longitudinal section, showing the primary vascular bundles diverging slightly from the base, and passing towards the blossom-end, giving off branches on the outside, which form a network with plume-like branchlets radiating towards the skin. The primary bundles are alternately opposite and intermediate to the carpels, and give off branches on the inside supplying each of the carpels dorsally and ventrally.

Fig.6.—Fibro-vascular bundles supplying two carpels, the two outer bundles being opposite to, and the inner one between the carpels. Each vascular bundle is seen branching outwardly, forming a network with plume-like branchlets, while, on the inner side, branches are given off to the carpels. The primary bundles, opposite to the carpels, branch and supply the dorsal face of each carpel, while those intermediate supply the ventral face.

Plate xxviii.

Fig.7.—General distribution of the vascular bundles, as shown when the skin is removed, and the flesh of the pear carefully detached. The main trunks, with their innumerable branches, ramify through every part, and form a complete outline of the fruit.(Slightly reduced).

Fig.8.—Same specimen as in Fig.7, with the various primary bundles spread out so as to expose the carpels. Each bundle is continued around and beyond the carpels to the blossom-end of the fruit. (Slightly reduced).

Plate xxix.

Fig.9.—Vascular network of Achan pear, a short distance beneath the skin, enveloping the flesh. The variable size and shape of the meshes are shown, as well as the plume-like branchlets.(Slightly reduced).

Fig.10.—Surface-view of skin of pear, showing the "window-cells," as in the apple, but somewhat smaller ($\times$ 100).

Fig.11.—Cross-section through skin and flesh, showing epidermis and hypo dermal layer, together with groups of "stone-cells" in the flesh ($\times$ 100).

Fig.12.—Cross-section of skin, showing thickened outer walls of epidermal cells (stained by fuchsin), and hypodermal layer with cells tangentially arranged, and vascular bundles reaching to them ($\times$ 100).